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पिटवां इस्पात के लिए अनुसूची

भाग 7 उच्च तापमान सेवाओं के लिए इस्पात
(मन्द निरूपण रोधी इस्पात)

Indian Standard

SCHEDULE FOR WROUGHT STEELS

PART 7 STEELS FOR ELEVATED TEMPERATURE SERVICE (CREEP RESISTANT STEELS)

(Second Reprint APRIL 1998)

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BUREAU OF INDIAN STANDARDS
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Price Group 7

Alloy Steels and Special Steels Sectional Committee, MTD 16

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Alloy Steels and Special Steels Sectional Committee, had been approved by the Metallurgical Engineering Division Council.

Schedules for wrought steels for general engineering purposes (IS 1570 : 1961) was first published in 1961. On the basis of the experience gained in the production and use of steels, the Sectional Committee has decided to revise the standard and issue it in parts. The other parts of the standard are as follows:

Part 1	Steels specified by tensile and/or yield properties
Part 2	Carbon steels (Unalloyed steels)
Part 3	Carbon and carbon manganese free cutting steels
Part 4	Alloy steels (excluding stainless and heat-resisting steels)
Part 5	Stainless and heat-resisting steels
Part 6	Tool steels

This schedule does not give limits for sulphur and phosphorus. These have to be specified in the detailed specifications.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard
SCHEDULE FOR WROUGHT STEELS

PART 7 STEELS FOR ELEVATED TEMPERATURE SERVICE (CREEP RESISTANT STEELS)

1 SCOPE

1.1 This Schedule (Part 7) covers the technical requirements and informations for wrought carbon, low alloy and high alloy steels for elevated temperature applications used for the construction of steam and water boilers, pressure vessels, turbines, water and steam pipe line as well as other power generating plants. They are delivered as strips, sheets, plates, pipe lines, forgings and forged, rolled or drawn bars as well as blooms and billets.

2 GENERAL

2.1 While preparing Indian Standards, or revising the existing standards, steels listed in this schedule shall be selected. The specification of mechanical properties different from those given in this schedule should not be made unless special conditions of service render this essential. In that event, full reasons for the proposed departure from the steels specified in this schedule shall be submitted to the Alloy Steels and Special Steels Sectional Committee, MTD 16 and its approval obtained.

2.2 The ladle analysis of the steels is given in Table 1. These steels have an increased resistance to creep due to their alloy contents. The permissible deviations between analysis and product analysis are given in Table 2 and the heat treatment schedule is given in Table 5.

2.3 These steels are suitable for hot working and cold forming operations and they may generally be welded by the usual welding processes. The hot working characteristics of austenitic steels should be noted.

2.4 In addition to defining the composition limits, the specified mechanical properties applicable to the different conditions are included. Table 3 gives the mechanical properties at room temperature and Table 4 gives proof stress at elevated temperature. Table 6 (for guidance only) include the data for steels for average creep stresses for 1 % elongation and rupture stresses for 10 000, 30 000, 51 000, 100 000, 150 000, 200 000 and 250 000 h.

2.5 The specified mechanical properties are applicable to test samples taken from a standard location which should be included in the specification.

Table 1 Type of Steel, Chemical Composition and Typical Forms

(*Clause* 2.2)

Type of Steel	Chemical Composition, wt. %											Typical Form
	C	Si	Mn	P *Max*	S *Max*	Cr	Mo	Ni	V	W	Others	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1) Fe360H	0·20 *Max*	0·10 to 0·35	0·40 to 1·20	0·03	0·03	0·25 *Max*	0·10 *Max*	0·30 *Max*	—	—	Cu 0·30 *Max*	Plates
2) Fe410H	0·20 *Max*	0·10 to 0·35	0·50 to 1·30	0·03	0·03	0·25 *Max*	0·10 *Max*	0·30 *Max*	—	—	Cu 0·30 *Max*	Plates
3) 12C7H	0·17 *Max*	0·10 to 0·35	0·40 to 1·00	0·045	0·045	0·25 *Max*	—	0·35 *Max*	—	—	Cu 0·30 *Max*	Seamless pipes and pipes with seam
4) 18C10H	0·15 to 0·22	0·10 to 0·35	0·60 to 1·40	0·045	0·045	—	—	0·35 *Max*	—	—	Cu 0·30 *Max*	do
5) 16Mo3H	0·12 to 0·20	0·10 to 0·35	0·40 to 0·80	0·04	0·04	0·30 *Max*	0·25 to 0·35	0·35 *Max*	—	—	Cu 0·30 *Max* Al met 0·02 *Max*	Seamless pipes bars forgings steel plates
6) 15Mo6H	0·10 to 0·20	0·10 to 0·50	0·30 to 0·80	0·045	0·045	—	0·44 to 0·65	—	—	—		
7) 10Mo6H	0·15 *Max*	0·50 to 1·00	0·30 to 0·60	0·030	0·030	1·00 to 1·50	0·45 to 0·60	—	—	—		
8) 20Mo5H	0·15 to 0·25	0·10 to 0·35	0·90 to 1·40	0·04	0·04	0·30 *Max*	0·40 to 0·60	0·30 *Max*	—	—	Cu 0·30 *Max* Al met 0·02 *Max*	Steel plates
9) 12Cr4Mo5H	0·10 to 0·18	0·10 to 0·35	0·40 to 0·70	0·040	0·70 to 1·10	0·45 to 0·65	—	—	—	—	Al met 0·02 *Max* seam	Seamless pipes and pipes with plates
10) 12Cr2Mo5V2H	0·10 to 0·18	0·10 to 0·35	0·40 to 0·70	0·040	0·30 to 0·60	0·50 to 0·70	—	0·22 to 0·32	—	—	Al met 0·02 *Max*	Seamless pipes plates
11) 12Cr9Mo10H	0·08 to 0·15	0·10 to 0·50	0·30 to 0·70	0·040	0·040	1·90 to 2·60	0·90 to 1·15	—	—	—	Al met 0·02 *Max*	Seamless pipes bars, forgings
12) 10Cr36Mo10H	0·15 *Max*	0·25 to 1·0	0·30 to 0·60	0·040	0·030	8·00 to 10·00	0·90 to 1·10	—	—	—	Al met 0·02 *Max*	Seamless pipes
13) 40CrMoH	0·35 to 0·45	0·10 to 0·35	0·40 to 0·70	0·035	0·035	1·00 to 1·50	0·50 to 0·80	—	—	—	—	Bar, forging
14) 21CrMoVH	0·17 to 0·25	0·40 *Max*	0·40 to 0·80	0·030	0·030	1·2 to 1·50	0·65 to 0·80	0·60 *Max*	0·25 to 0·35	—	—	do
15) 40CrMoVH	0·86 to 0·44	0·10 to 0·35	0·45 to 0·85	0·030	0·03	0·9 to 1·2	0·55 to 0·75	—	0·25 to 0·35	—	—	do
16) 20CrMoVTiBH	0·17 to 0·24	0·35 *Max*	0·5 *Max*	0·03	0·03	0·90 to 1·40	0·8 to 1·10	0·50 *Max*	0·7 to 1·0	—	Ti 0·05 to 0·12 B 0·005	Bars, forgings
17) 25Cr2MoVH	0·20 to 0·30	0·20 to 0·50	0·30 to 0·60	0·030	0·025	1·5 to 1·80	0·90 to 1·20	0·40 *Max*	0·20 to 0·30	—	Cu 0·30 *Max*	Forgings
18) 20Cr2MoVH	0·20 to 0·30	0·20 to 0·50	0·30 to 0·60	0·030	0·030	1·5 to 1·80	0·60 to 0·80	0·40 *Max*	0·20 to 0·30	—	Cu 0·30 *Max*	Bars, forgings
19) 12Cr13H	0·09 to 0·15	1·00 *Max*	1·00 *Max*	0·040	0·030	11·5 to 14·00	—	1·00 *Max*	—	—	—	Bar, forging plates

Table 1 (*concluded*)

Type of Steel	Chemical Composition, wt. %											Typical Form
	C	Si	Mn	P *Max*	S *Max*	Cr	Mo	Ni	V	W	Others	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
20) 12Cr12MoH	0·08 to 0·16	0·60 *Max*	0·40 to 1·00	0·040	0·035	11·5 to 13·00	0·40 to 0·80	1·0 *Max*	—	—	—	Bar, forging
21) 12Cr12MoVH	0·08 to 0·16	0·60 *Max*	0·40 to 1·00	0·040	0·035	11·5 to 13·00	0·40 to 0·80	1·0 *Max*	0·10 to 0·30	—	—	Bar, forging
22) 12Cr12Ni2Mo	0·08 to 0·16	0·35 *Max*	0·50 to 0·90	0·040	0·030	11·0 to 12·5	1·5 to 2·00	2·0 to 3·0	0·25 to 0·40	—	N 0·02 to 0·04	Bar, forging plate
23) 20Cr12MoNi VH	0·17 to 0·23	0·50 *Max*	1·00 *Max*	0·040	0·030	11·0 to 12·50	0·7 to 1·20	0·30 to 1·00	0·20 to 0·35	—	—	Bar, forging seamless
24) 20CrNiMoNb VH	0·16 to 0·24	0·10 to VH	0·3 to 0·24	0·040 to 0·50	0·030 to 1·00	10 to 12	0·5 to 1·0	0·3 to 1·00	0·1 to 0·30	—	B 0·008 *Max* Mn. 10 *Max* Nb 0·2 to 0·50	Bar forging
25) 7Cr18Ni10H	0·04 to 0·10	0·75 *Max*	2·00 *Max*	0·045	0·030	17·00 to 20·00	—	8·00 to 12·00	—	—	—	Seamless tubes, plates bars, forgings
26) 3Cr18Ni11H	0·030 *Max*	1·00 *Max*	2·00 *Max*	0·045	0·030	17·00 to 19·00	—	9·00 to 13·00	—	—	—	Plates, forgings seamless tubes
27) 6Cr17Ni12 Mo2H	0·08 *Max*	1·00 *Max*	2·00 *Max*	0·045	0·030	16·00 to 18·00	2·00 to 3·00	10·00 to 14·00	—	—	—	Seamless pipes, bars, forgings plates
28) 3Cr17Ni12Mo 3H	0·030 *Max*	1·00 *Max*	2·00 *Max*	0·045	0·030	16·00 to 18·00	2·00 to 3·00	10·00 to 14·00	—	—	—	Plates, seamless tubes
29) 7Cr19Ni11 TiH	0·04 to 0·10	0·20 to 0·80	2·00 *Max*	0·045	0·030	17·00 to 20·00	—	9·00 to 13·00	—	—	Ti > 4xc < 0·60	Seamless pipes, bars forgings
30) 7Cr18Ni11 NbH	0·04 to 0·10	0·75 *Max*	2·00 *Max*	0·045	0·030	17·00 to 19·00	—	9·00 to 13·00	—	—	Nb + Ta > 10xc < 1·00	Seamless pipes, bars, forgings, plates
31) 11Cr17Ni 13W3TiH	0·07 to 0·15	1·00 *Max*	1·00 *Max*	0·045	0·030	15·5 to 17·50 00·006 0	— forgings	12·00 to 14·50	—	2·5 to 3·5	Ti > 4xc < 0·80 B 0·000 6 *Max*	Seamless pipes, bars forgings
32) 6Ni25Cr15Ti 2MoVBH	0·03 to 0·08	1·00 *Max*	2·00 *Max*	0·045	0·030	13·5 to 16·00	1·00 to 1·50	24·00 to 27·00	—	0·10 to 0·50	Ti 1·9 to 2·30 Al met 0·35 *Max* B 0·003 to 0·010	Bars forgings, Seamless pipe

Element not quoted in this table shall not be intentionally added to the steel without the agreement of the purchaser, other than for the purpose of finishing the heat. All reasonable precautions shall be taken to prevent the addition, from scrap or other materials used in manufacture, of such elements which effect the hardenability mechanical properties and applicability.

Table 2 Permissible Deviation Between Specified Analysis and Product Analysis

(*Clause* 2.1)

Element %	Permissible Deviations*
C up to 0·25	± 0·02
C above 0·25	± 0·03
Si up to 1·0	± 0·05
Mn up to 2·0	± 0·05
P up to 0·05	+ 0·005
S up to 0·05	+ 0·005
Cr up to 1	+ 0·03
Above 1 up to 2·5	± 0·05
Above 2·5 up to 10·00	± 0·10
Above 10·0	± 0·15
Ni up to 1	+ 0·03
Above 1 up to 2·5	± 0·05
Above 10·0	± 0·10
Mo up to 1	+ 0·03
Above 1	± 0·05
V	± 0·02
Cu	± 0·02
Al	± 0·005
Nb	± 0·005
W	+ 0·10

*The deviations, other than when maximum or minimum only are specified, apply either above or below the specified limits of the range but not both above and below for the same element from sample products from the same cast.

Table 3 Mechanical Properties at Room Temperature

(*Clause* 2.4)

Type of Bend7) Steel	Product	Heat1) Treatment	Thickness mm		Hardness2) RB	R_p0·2 3) *Min* MPa	R_m 4) MPa		% *Min*	A5) KV6) *Max* J	Bend7) Test D *Max*
			Over	Up to and Including			*Min*	*Max*			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1	Plate	N	3	16	—	205	360	480	26	—	0·5 a
			16	40		195			26		
			40	63		185			25		
			63	100		175			24		
			100	150		170			24		
2	Plate	N	3	16	—	225	410	520	24	—	2 a
			16	40		215			24		
	Quadrangular seamless pipe		40	63		205			23		
			63	100		200			22		
			100	150		195			22		
3	Seamless pipe and pipe with seam	N	—	—	—	215	360	480	24	—	4 a
4	Seamless pipe and pipe with seam	HFaN	—	—	—	265	460	580	22	—	4 a
5	Seamless pipes, steel plates	N,N+T	3	16	—	260	440	590	24	—	3 a
			16	40		250			24		
			40	63		250			23		
			63	100		Note 8			22		
	Bars, forgings	Q + T	—	—	—	250	440	590	17		
6	Tubes	N + T	—	—	—	205	380	—	22	—	—
7	Tubes	N + T	—	—	—	205	415	—	30	—	—
8	Steel plates	N + T	3	16	—	355	510	660	21	—	3 a
			16	40		345			21		
			40	63		345			20		
			63	100		Note 8			19		
9	Pipes	N + T	—	—	—	275	440	590	22	—	—
	Plates	N + T	3	16		305			20		
			16	40		305	470	620	20	—	3 a
			40	63		305			19		
			63	100		Note 8			18		
	Bars, forgings	N + T	—	—	255	410	560	—	18	—	—
		Q + T	—	—	—	375	540	690	15	—	—
10	Pipes	N + T	—	—	—	275	460	610	15	—	—
	Plates	N + T	3	16	—	285					
			16	40		285	460	610	19	—	3·5 a
			40	63		285					
			63	100		Note 8					
	Bars,	N + T									
	forgings	Q + T	—	—	—	275	460	610	16	—	—
11	Pipes	A	—	—	—	135	410	560	200	—	—
		N + T	—	—	—	275	490	640	16	—	—
	Bars, forgings	M + T	—	—	—	275	490	640	16	—	—
		Q + T	—	—	—	335	540	690	15	—	—
12	Pipes	A	—	—	—	135	410	560	20	—	—
		N + T	—	—	—	390	590	740	18	—	—
13	Bars, forgings	Q + T	—	200	—	635	850	1 000	14	30	—
14	Bars, forgings	Q + T	—	250	205-250	550	700	850	16	63	—
15	Bars, forgings	Q + T	—	100	—	700	850	1 000	14	30	—
			100	200		635	800	950	14	25	—
16	Bars, forgings	Q + T	—	200	241-269	680-780	800	—	15	—	—
17	Forgings of turbine shafts	N + T	—	900	At the average 200	420	630	—	16	—	—
			—	—	do	500	630	—	16	—	—
18	Bars, forgings	Q + T	—	—		550	700	850	17	—	—
		N + T	—	600	220	450	650		16	—	—

Table 3 (*concluded*)

Type of Bend 7) Steel	Product	Heat 1) Treatment	Thickness mm Over	Thickness mm Up to and Including	Hardness 2) RB	Rp0·2 3) *Min* MPa	Rm 4) MPa *Min*	Rm 4) MPa *Max*	% *Min*	A 5) KV 6) *Max* *J*	Bend 7) Test *D* *Max*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
19	Bars, forgings	A	—	160	—	265	470	670	20	60	—
	plates		0·5	25							
	Bars, forgings	Q + T	—	160	175-235	420	590	780	16	40	—
			0 5	25							
20	Bars, forgings	Q + T	—	75	> 192	490	680	880	20	—	—
21	Bars, forgings	Q + T	—	150	—	585	770	930	15	25	—
22	Bars, forgings	Q + T	—	150	285-331	785	930	1 130	14	40	—
	plates		0·5	6	280-330	785	930	1 130	10	—	—
23	Bars, forgings	$Q + T_1$	—	250	255-280	590	780	930	14	27	—
	Seamless pipe	$Q + T_2$	—	250	265-310	700	900	1 050	11	20	—
24	Bars, forgings	Q + T	—	250	265-310	750	900	1 050	10	20	—
25	Tubes, forgings	Q	—	—	—	195	490	690	30	—	—
	plates		3	40	—	195	490	690	50	—	—
			40	63					45	—	—
26	Tubes, forgings	Q	—	—	—	175	490	690	30	—	—
	plates		3	30	—	175	440	640	50		
			30	50					45	—	—
27	Pipes, bars	Q	—	—	—	205	510	710	30	—	—
	forgings plates		3	40	—	205	490	690	40	—	—
			40	63		205			35		
28	Tubes, plates	Q	—	—	—	185	490	690	30	—	—
			3	40	—	185	440	640	45	—	—
			40	63	—				400	—	—
29	Pipes	Q_1	—	—	—	155	490	690	30	—	—
	bars, forgings	Q_2	—	—	—	195	510	710	30	—	—
30	Pipes,	Q	—	—	—	205	510	710	30	—	—
	bars, forgings		3	40	—	205	490	690	40	—	—
	plates		40	63	—	205			35	—	—
31	Bars, forgings	hot cold	—	60	175-235	390	600	800	25	55	—
	pipes	worked									
		S + P		100	—	220	500	730	35	70	—
32	Bars, forgings	S + P	5	250							
	pipes				248-341	600	900	1100	15	40	—
	plates		0·5	63							

1) A = Annealed, N = normalised, Q = quenched, T = tempered, S = solution treated, P = precipitation hardened. HF = hot finished

2) In case of dispute, the tensile strength value is deciding.

3) R_p 0·2 = 0·2 % proof stress.

4) R_m = tensile strength.

5) A = elongation after fracture. In case, of bars the values are valid for test pieces with a gauge length of Lo = 5·65 $\sqrt{S_o}$ (S_o = original cross-sectional area). In the case of flat products, the values are valid for both test pieces either of 20 mm width and 80 mm gauge length or of 12·5 width and 50 mm gauge length.

6) Average of three test results. One individual value may be below the specified value provided if it is not less than 70% of that value.

7) KV = impact energy of V-notch test pieces.

8) D_{max} = maximum diameter of mandrel, a = thickness of test piece.

9) For thickness > 63 mm but < 100 mm, the value specified for the thickness range > 40 mm but < 63 mm are lowered by 1% for each 5 mm thickness over 63 mm.

Table 4 Proof Stress at Elevated Temperatures (For Guidance Only)

(*Clause* 2.4)

Type of Steel	Product	Heat1) Treatment	Thickness mm		R_p 0·2 Min in MPa at Temperature °C														
			Over	Up to and Including	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
1	Plate	N	3	16	—	172	168	150	124	117	115								
			16	40	—	169	162	144	124	117	115								
			40	63	—	158	152	141	124	117	115								
			63	100	—	148	144	136	124	117	115								
2	Plate	N	3	16	—	200	195	174	145	137	133								
			16	40	—	192	185	165	145	137	133								
			40	63	—	182	175	162	145	137	133								
			63	100	—	170	166	157	145	137	133								
3	Seamless pipes and pipe with seam	HF, N		40	187	176	165	145	122	111	109	107							
4	Seamless pipes and pipe with seam	HF, N		40	234	223	212	195	177	162	159	156							
5	Seamless pipes, bars, forgings steel plates	N, N + T Q + T			237	232	218	200	167	153	148	143	139						
6	Tubes	N + T																	
7	Tubes	N + T																	
8	Steel plates	N + T					lack of data												
9	Pipes	N + T	—	40	240	230	220	210	183	169	164	161	156	151	146				
	Plates	N + T,	—	60	270	259	248	237	116	203	199	194	188	181	174				
	Bars, forgings	N+T, Q +T	—	—	210	200	192	180	150	135	130	127	124	120	117				
10	Pipes, plates, Bars, forgings	N+T, N +T N+T, Q +T		—	259	248	235	218	192	184	177	168	155	148	135				
11	Pipes, bars,	A	—	—	108	99	92	85	80	76	72	69	66						
	forgings	N + T, N+T, Q +T	—	—	261	253	245	236	230	224	218	205	189	167	145				
12	Pipes	A	—	—	98	88	79	78	77	76	75	74	71						
		N + T	—	—	363	348	334	330	326	322	316	311	290	235					
13	Bars, forgings	Q + T	—	—	630		610		575		525	490	450						
14	Bars, forgings	Q + T	—	—	530		500		460		410	380	350						
15	Bars, forgings	Q + T_1	—	—	670		635		598		540	500	460	403					
		Q + T_2	—	—	630		615		580		525	480	435	—					
16	Bars, forgings	Q + T					lack of data												
17	Forgings	N + T	—	900			330	350	340	330	320	—							
			—	—			460	440	420	400	370	330							
18	Bars, forgings	N + T	—	100			500	480	460	440	410	380	350						
			100	500					to be agreed upon										
19	Bars, forgings plates	A	—	—	235		240		225		205	195	185	175					
	Bars, forgings plates	Q + T	—	—	410		380		345		305	285	—	—					

Table 4 (*concluded*)

Type of Steel	Product	Heat[1]) Treatment	Thickness mm		Rp 0·2 Min in MPa at Temperature °C														
			Over	Up to and Including	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
20	Bars, forgings	Q + T	—	—	480		450		410		380	360	330	—					
21	Bars, forgings	Q + T	—	—	575		555		535		510	480	450	—					
22	Bars, forgings plates	Q + T	—	—	680		655		650		610	560	505	400	250				
23	Bars, forgings	Q + T_1	—	—	560		530		480		420	380	335	280	205				
	Seamless pipes	Q + T_2	—	—	650		600		550		485	440	390	330	250				
24	Bars, forgings	Q + T	—	—	730		700		655		580	530	470	400	315				
25	Tubes, forgings, plates	Q	—	—	132	120	109	100	93	87	84	81	79	78	76				
26	Tubes, forgings, plates	Q	—	—		lack of data													
27	Pipes plates bars forgings	Q	—	—	155	144	132	121	113	107	101	89	95	92	90	89	88		
28	Tubes, plates	Q	—	—		lack of data													
29	Pipes bars,	Q_1	—	—	107	103	97	94	90	85	80	76	74	73	72	71	70		
	forgings	Q_2	—	—	148	144	139	134	130	124	119	114	111	107	104	101	99		
30	Pipes bars, forgings, plates	Q	—	—	171	162	153	149	139	133	129	125	123	122	120				
31	Pipes bars, forgings	Hot cold worked	—	—	383		373		324		275	250	226	197	167				
		S + P	—	—	210		195		176		157	155	152	143	137				
32	Pipes, bars, forgings, plates	S + P	—	—	590		570		555		535	520	510	490	465	425	375	305	225

[1]) A = annealed, N = normalised, Q = quenched, T = tempered, S = Solution, P = precipitation hardened.

Table 5 Heat Treatment[1)]

(*Clause* 2.2)

Type of Steel	Heat Treatment Symbols[2)]	Normalisation			Tempering		Stress Relief of Annealing or Tempering after Bending or Welding		Quenching and Tempering			
									Quenching		Tempering[3)]	
		Temperature °C	Time of Holding at Temperature	Cooling[3)]	Temperature °C	Time of Holding at Temperature	Temperature °C	Time of Holding Temperature	Temperature °C	Cooling	Temperature °C	Time of Holding at Temperature
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1	N	900-930	1 to 2 min per 1 mm	In quiet air	—	—	600-650	2 min per 1 mm	—	—	—	—
2	N	890-920	Thickness of plate but not less than 20 min	In quiet air	—	—	600-650	Thickness of plate but not less than 30 min	—	—	—	—
3 and 4	HF, N	880-940	1 to 2 min per 1 mm thickness of pipe wall but not less than 20 min	In quiet air	—	—	600-650	2 min per 1 mm	—	—	—	—
					—	—	600-650	Thickness of pipe wall but not less than 15 min	—	—	—	—
5	N	900-940	1 to 2 min per 1 mm thickness of forging or pipe wall but not less than 20 min	In quiet air	600-650	1·5 to 2 min per 1 min thickness of pipe wall	600-650	do	900-940	Oil or water	600-650	—
6												
7												
8	N + T	880-930	1 to 2 min per 1 mm thickness of plate but not less than 20 min	In quiet air	600-650	1 to 3 min per 1 min thickness but not less than 15 min	600-650	2 min per 1 mm thickness but not less than 15 min	—	—	—	—
9	N + T	900-960	1 to 2 min per 1 mm thickness of forging or pipe wall but not less than 20 min	In quiet air	640-720	1 to 3 min per 1 mm thickness but not less than 15 min	660-710	2 min per 1 mm thickness but not less than 15 min	900-930	Oil or water	620-720	—

Table 5 (*concluded*)

Type of Steel	Heat Treatment Symbols2)	Normalisation			Tempering		Stress Relief of Annealing or Tempering after Bending or Welding		Quenching and Tempering			
									Quenching		Tempering3)	
		Temperature °C	Time of Holding at Temperature	Cooling3)	Temperature °C	Time of Holding at Temperature	Temperature °C	Time of Holding Temperature	Temperature °C	Cooling	Temperature °C	Time of Holding at Temperature
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
10	N + T Q + T	930-980	1 to 2 min per 1 mm thickness of forging or pipe wall but not less than 20 min	For pipes in quite air, for forgings of 50 mm thickness in quiet air, above 50 to 100 in compressed air and above 100 mm in oil	670-720	min 3 h	680-740	—	975-1 000	Oil	730-750	—
11	N + T Q + T	900-960	1 to 2 min per 1 mm thickness of forging or pipe wall but not less than 20 min	do	650-780	1 to 3 min per 1 mm thickness but not less than 15 min	730-760	2 min per 1 mm thickness but not less than 15 min	930-1 030	Oil or water	650-760	—
12	A N + T	850-950 900-1 000	1 to 2 min per 1 mm thickness of forging or pipe wall but not less than 20 min	Air	700-800	1 to 3 min per 1 mm thickness but not less than 15 min	760-820	2 min per 1 mm thickness but not less than 15 min	—	—	—	—
13	Q + T		—	—	—	—	—	—	840-870	Oil	600-700	—
14	Q + T	900-950	—	Air	380-680	—	480-650	—	920-980	Air Oil	680-740	min 2 h
15	Q + T* Q + T*	— —	— —	— —	— —	— —	— —	— —	880-950 940-970	Oil Oil	670-720 600-700	— —
16	Q + T	—	—	—	—	—	—	—	—	—	—	—
17	N + T	940-970	—	Quiet air	690-760	—	—	—	—	—	—	—
18	N + T	970-990	—	Quiet air	680-700	—	—	—	870-900	Oil	600-700	min 2 h
19	A Q + T	700-780	—	Air	—	—	—	—	950-1 000	Air, Oil	700-750	min 2 h

20	Q + T	—	—	—	—	—	—	—	970-1 020	Oil	650-750	min 2 h
21	Q + T	—	—	—	—	—	—	—	1 050 ± 10	Air, oil	650-700	—
22	Q + T	—	—	—	—	—	—	—	1 035-1 065	Oil	600-700	—
23	Q + T1	—	—	—	—	—	740-780	—	1 020-1 070	Air, oil, water	680-740	min 2 h
	Q + T2	—	—	—	—	—	740-780	—	1 020-1 070	do	640-700	min 2 h
24	Q + T	—	—	—	—	—	—	—	1 100-1 150	Air, Oil	670-750	min 2 h
25	Q	—	—	—	—	—	—	—	980-1 100	Oil, air, water	—	—
26	Q	—	—	—	—	—	—	—	950-1 100	Air, water oil	—	—
27	Q	—	—	—	—	—	—	—	1 100-1 100	Air, (rapidly) oil, water	—	—
28	Q	—	—	—	—	—	—	—	850-1 100	Air, water oil	—	—
29	Q1	—	—	—	—	—	—	—	1 070-1 140	do	—	—
	Q2	—	—	—	—	—	—	—	950-1 070	do	—	—
30	Q	—	—	—	—	—	—	—	950-1 100	Air, water oil	—	—
31	Hot cold worked at about 750°C	—	—	—	—	—	—	—	—	—	—	—
32	S + P	—	—	—	—	—	—	—	1 100-1 150	Air, water	750-800	—
33	S + P	—	—	—	—	—	—	—	980 ± 10	Oil, water	720 ± 10	—

*Q + T_1 would apply to sizes up to 100 mm, Q + T^2 to sizes above 100 up to 200 mm.

1) Except in cases where test samples are to be reference heat treated, the indications in this table are for guidance only.

2) A = annealed, N = normalised, P = precipitation hardened, Q = quenched, S = solution treated, T = tempered.

3) If a stress relief treatment is necessary, the stress relief temperature should be at least 30°C lowar than the tempering temperature.

Table 6 Stress Rupture Properties at Elevated Temperatures (For Guidance Only)

(*Clause* 2.4)

Type of Steel	Heat Treat-ment Symbol	Time Hours	Estimated Average Stress for Rupture[1], MPa, Temperature °C																					
			380	390	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)
1 and 2	N	10 000	213	197	181	166	151	138	125	112	100	89	78	67	57										
		30 000	192	176	181	147	133	120	107	95	84	73	63	52*	42*										
		50 000	183*	167	152	138	125	112	100	88	77	66	50*	40*	35*										
		100 000	171*	155*	141*	127*	114*	102*	90*	78*	67*	57*	47*	36*											
		150 000	164*	149*	134*	121*	108*	96*	84*	73*	62*	52*	41*	29*											
		200 000	159*	144*	130*	116*	104*	92*	80*	69*	50*	48*	37*	23*											
		250 000	155*	140*	126*	113*	101*	89*	77*	66*	55*	45*	34*												
3	N	10 000	221	201	181	164	148	132	118	104	91	78	68	59	51										
		30 000	192	175	157	140	124	108	94	81	70	68	51*	43*	(36)*										
		50 000	181*	163*	145*	128*	112*	97*	82*	70*	59*	50*	43*	36*	(30)*										
		100 000	164*	145*	127*	110*	94*	79*	68*	56*	46*	39*	(33)*												
		150 000	153*	135*	119*	101*	84*	71*	59*	48*	40*	(34)*	(28)*	—	—										
		200 000	146*	128*	111*	93*	77*	64*	53*	44*	(36)*	(30)*		—	—										
		250 000	140*	123*	104*	86*	72*	59*	49*	40*	(33)*	(27)*	—	—	—										
4	N	10 000	279	254	229	206	183	163	145	127	113	100	88	78	71										
		30 000	251	224	197	174	152	133	117	101	88	77	68	60	(52)										
	HF	50 000	237	206	179	158	137	119	103	88	76	67	59	(52)	(45)										
		100 000	211*	182*	157*	135*	117*	100*	88*	83*	57*	50*	(45)*	—	—										
		150 000	196*	168*	144*	124*	104*	87*	75*	66*	(56)*	(48)*		—	—										
		200 000	185*	157*	135*	114*	95*	79*	69*	59*	(50)*	—	—	—	—										
		250 000	177*	156*	127*	106*	88*	75*	64*	55*	(46)*	—	—	—	—										
5	N	10 000								298	273	247	220	196	171	147	125	102	82	64					
	N + T	30 000								273	244	216	187	150	134	113	93	76	61	49					
	Q + T	50 000								260*	229*	208*	172	144	119	99	80	66	53	(42)*					
		100 000								239*	208*	178*	148*	123*	101	81	66	53*	(42)*	(34)*					
		150 000								226*	197*	168*	139*	114*	91*	74*	60*	48*	(39)*	—					
		200 000								217*	188*	159*	130*	105*	84*	69*	55*	45*	(36)*	—					
		250 000								210*	180*	151*	124*	100*	68*	65*	52*	(42)*	(33)*	—					
8	N + T										lack of data														
9	N + T	10 000											304	273	239	209	179	154	129	109	91	76	64	53	44
	Q + T	30 000											267	233	200	169	140	116	96	79	66	54	44	36	(29)
		50 000											239	207	177	149	124	101	82	68	55	45	—	—	—
		100 000											210	177	146	121	99	81	67	54	43	35	—	—	—
		150 000											194*	161*	132*	108*	87*	71	57	46	38	(31)	—	—	—
		200 000											180*	148*	122*	99*	79*	64*	52*	42*	34*	(28)*	—	—	—
		250 000											170*	139*	114*	91*	74*	59*	48*	39*	32*	(26)*	—	—	—

Table 6 *(continued)*

Type of Steel	Heat Treatment Symbol	Time Hours	Estimated Average Stress for Rupture$^{3)}$, MPa, Temperature °C																												
			380	390	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630	640	650	660
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)
																				610	620	630	640	650	660						
10	N + T	10 000																													
	Q + T	30 000											929	268	241	219	198	179	164	148	134	121	108	95	78						
		50 000											261	232	209	187	168	152	135	121	107	93	80	67	(50)						
		100 000											243	217	193	172	153	136	121	107	92	78	66	—	—						
		150 000											218	191	170	150	131	116	100	85	72	59	(46)*	—	—						
		200 000											205	179	156	136	119	101*	85*	70*	57*	(45)*	(35)*	—	—						
		250 000											194*	169*	146*	127*	109*	91*	76*	61*	(48)*	(37)*	(28)*	—	—						
													185*	160*	138*	119*	101*	83*	68*	54*	(42)*	(32)*	—	—	—						
11	A	10 000								251*	236*	221*	206	191	177	162	147	133	121	108	96	85	76	68	61						
	N + T	30 000								226*	211	196*	181	168	153	139	126	113	101	89	78	70	61	54	48						
		50 000								211*	197*	183*	170*	156*	142*	128*	116*	104	92	81	71	62	54	47	42						
		100 000								196*	182*	168*	154*	141*	127*	115*	102*	93*	78*	69*	59	51	44	(38)*	(34)*						
		150 000								193*	177*	161*	145*	129*	116*	103*	91*	79*	71*	62*	54*	46*	40*	(35)*	(30)*						
		200 000								186*	170*	154*	138*	123*	110*	97*	85*	75*	66*	58*	50*	43*	(37)*	(32)*	(28)*						
		250 000								181*	165*	149*	132*	118*	105*	93*	81*	72*	63*	54*	47*	40*	(35)*	(30)*	(26)*						
	N + T	10 000								309*	285*	263*	240	219	196	176	155	137	122	108	96	85	76	68	61						
		30 000								276*	254*	233*	213	192	172	152	134	118	103	90	79	70	61	54	48						
		50 000								257*	236*	217*	197*	177*	158*	139*	123*	107*	93	80	71	62	54	47	42						
	Q + T	100 000								221*	204*	186*	170*	153*	137*	122*	107*	93	79	69	59	51	44	(38)	(34)*						
		150 000								209*	192*	175*	158*	141*	126*	110*	95*	82*	73*	63*	54*	47	40	(33)	(30)*						
		200 000								203*	186*	169*	152*	135*	119*	103*	89*	77*	68*	58*	50*	43	(37)*	(32)*	(28)*						
		250 000								198*	181*	164*	147*	130*	113*	98*	84*	74*	64*	55*	47*	41*	(35)*	(30)*	(26)*						
12	A	10 000													181	161	142	127	112	99	86	76	67	58	50	(44)*	(38)	33	28	25	
		30 000													159*	137*	121*	104*	90*	79*	69*	60*	52*	45*	38*	33*	28*	25*	22*	19*	
		50 000													147*	127*	111*	95*	82*	73*	62*	53*	46*	39*	33*	28*	25*	21*	18*	(16)*	
		100 000													131*	113*	96*	83*	72*	62*	53*	45*	38*	32*	27*	25*	20*	(17)*	(14)*	(11)*	
		150 000													123*	105*	90*	76*	65*	56*	47*	40*	33*	28*	24*	21*	(17)*	(15)*	(13)*	—	
		200 000													116*	99*	84*	72*	61*	52*	44*	37*	31*	25*	22*	19*	(16)*	(14)*	—	—	
		250 000													111*	95*	80*	68*	58*	49*	41*	34*	28*	25*	21*	(17)*	(15)*	—	—	—	
		10 000													224	199	177	157	138	121	104	91	79	69	60	51	44	38	33	28	25
		30 000													197*	174*	142*	133	116	100	85	74	63	54	46	39	34	29*	26*	22*	(18)*
		50 000													185*	162*	141*	123*	106*	90*	77*	67*	57*	47*	41*	35*	29*	25*	19*	(18)*	(16)*
		100 000													167*	144*	124*	106*	91*	78*	66*	57*	47*	40*	34*	28*	24*	21	(17)*	(15)*	(12)*
		150 000													156*	136*	117*	100*	85*	74*	62*	52*	43*	36*	30*	30*	25*	22*	(18)*	(16)*	(13)
		200 000													150*	129*	111*	94*	80*	69*	57*	48*	40*	33*	27*	24*	20*	(17)*	(14)*	—	—
		250 000													145*	125*	106*	90*	76*	65*	54*	45*	37*	31*	26*	22*	19*	(16)*	(13)	—	—
17 and		10 000					370	452	434	412	388	361	331	296	262	235	210	185	163	141											
18		100 000					944	374	352	328	303	271	248	219	187	159	134	112	94	75											

Table 6 (*continued*)

Type of Steel	Heat Treat-ment Symbol[1]	Time Hours	Estimated Average Creep Stress in 1 % Elongation at a Temperature °C								MPa for Rupture at a Temperature °C					
			450	500	550	600	650	700	750	450	500	550	600	650	700	750
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
13	Q + T	10 000								478	247	90				
		100 000								347	136	—				
14	Q + T	10 000	355	230	140					405	282	163				
		100 000	288	170	74					323	185	93				
15	Q + T	10 000								494	286	127				
		100 000								371	170	—				
16	Q + T		lack of data													
19	A	10 000		123	—	29					191	—	69			
		100 000		78	—	25					123	—	47			
	Q + T	10 000		150[2]	90[2]	40[2]					200[2]	130[2]	60[2]			
		100 000		80[2]	50[2]	25[2]					120[2]	75[2]	45[2]			
20	Q + T	10 000		137	38	39					206	98	44			
21	Q + T	10 000									270	200	92			
22	Q + T	10 000									347	157	96			
		100 000									215	102	57			
23	Q + T_1	10 000	436	289	165	79				480	338	211	103			
	Q + T_2	100 000	373	221	108	44				432	275	137	59			
24	Q + T	10 000		347	245	137	59				392	274	157	69		
31	Hot Cold	10 000									460	373	226	127	68	
	Worked	100 000									392	284	137	68	29	
	S + P	10 000				164	109	74	45				191	135	100	67
32	S + P	10 000		579	441	324	196	98			608	490	363	216	127	

Table 6 (*concluded*)

Type of Steel	Heat Treatment Symbol[1]	Time Hours	Estimated Average Stress for Rupture[2], MPa, Temperature °C																					
										610	620	630	640	650	660	670	680	690	700	710	720	730	740	750
(1)	(2)	(3)	(4)(5)(6)(7)(8)(9)(10)(11)(12)(13)(14)(15)(16)(17)(18)(19)(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	(36)	(37)	(38)	(39)	(40)	(41)
25	Q	10 000		176	164	152	142	131	122	113	104	95	87	79	73	67	61	55	48					
		30 000		147*	135*	126*	115*	105*	96*	88*	80*	74*	67*	61	55	50	44	(40)*	(35)*					
		50 000		134*	123*	113*	103*	94*	85*	70*	72*	65*	58*	52*	47*	41*	(36)*	(82)*	(27)*					
		100 000		115*	105*	98*	89*	81*	74*	68*	61*	55*	50*	45*	(40)*	(35)*	(30)*	(26)*	(23)*					
		150 000		108*	99*	89*	81*	74*	67*	60*	54*	49*	43*	(39)*	(34)*	(30)*	(36)*	(23)*	(20)*					
		200 000		102*	93*	84*	76*	69*	62*	56*	50*	45*	(40)*	(35)*	(31)*	(27)*	(24)*	(21)*	—					
		250 000		97*	88*	79*	73*	66*	59*	58*	47*	42*	(37)*	(33)*	(29)*	(25)*	(22)*	—	—					
26	Q			lack of data																				
27	Q	10 000		260	245	228	211	195	179	164	149	136	123	111	99	89	80	74	65	59	53	48	44	39
		30 000		243	224*	204*	187*	171*	155	139	125	112	100	89	79	72	64	57	51*	46	41	37*	33*	30*
		50 000		226*	208*	192*	175*	158*	142	128	115	103	91	80	72	63	56*	50	45*	40*	36*	32*	29*	(26)*
		100 000		196*	180*	160*	147*	132*	118*	106*	96*	86*	76*	69*	60*	53*	46*	41*	37*	33*	30*	27*	(25)*	(23)*
		150 000		187*	171*	152*	139*	124*	110*	97*	86*	76*	68*	60*	53*	47*	41*	36*	32*	28*	(25)*	(24)*	(21)*	—
		200 000		181*	165*	146*	133*	116*	103*	91*	80*	71*	63*	56*	49*	43*	38*	33*	29*	(26)*	(24)*	(22)*	(20)*	—
		250 000		176*	159*	140*	127*	110*	97*	86*	76*	67*	59*	52*	46*	40*	35*	31*	28*	(25)*	(23)*	(21)*	(19)*	—
28	Q			lack of data																				
29	Q	10 000				197	182	170	157	145	134	124	114	104	95	86	77	(70)*	(63)					
		30 000				167*	154	142	130	120	109	99	90	82	75	(67)*	(60)*	(53)*	(47)*					
		50 000				154*	142*	130*	120*	110*	100*	91*	82*	75*	(67)*	(60)*	(54)*	(47)*	(42)*					
		100 000				137*	126*	116*	106*	97*	88*	78*	71*	(64)*	(57)*	(50)*	(44)*	(39)*	(34)*					
		150 000				130*	119*	109*	99*	89*	80*	73*	(65)*	(57)*	(50)*	(44)*	(38)*	(33)*	—					
		200 000				125*	113*	103*	93*	84*	76*	(68)*	(60)*	(53)*	(46)*	(40)*	(35)*	(30)*	—					
		250 000				120*	109*	99*	89*	80*	72*	(64)*	(57)*	(50)*	(43)*	(37)*	(32)*	—	—					
	Q2	10 000				185	170	156	142	130	120	110	101	92	82	74	65	(57)*	(48)*					
		30 000				154*	141	128	118	107	98	88	79	71	61	(53)*	(46)	(40)*	(34)*					
		50 000				139*	127*	117*	107*	97*	87*	77*	69*	60*	(52)*	(44)*	(37)*	(37)*	(27)*					
		100 000				123*	112*	102*	92*	82*	74*	64*	(55)*	(47)*	(40)*	(36)*	(31)*	(27)*	(23)*					
		150 000				112*	102*	93*	83*	73*	64*	55*	(47)*	(41)*	(35)*	(30)*	—	—	—					
		200 000				106*	96*	86*	76*	67*	58*	(50)*	(43)*	(37)*	(32)*	(27)*	—	—	—					
		250 000				101*	92*	81*	72*	62*	(54)*	(46)*	(40)*	(34)*	(29)*	—	—	—	—					
30	Q	10 000	243	228	215	200	186	173	159	146	134	124	114	104	95	86	77	69	61	54	46			
		30 000	210*	190	184	172	159	146	133	123	112	102	92	83	74	66	58	51	44	38	(33)			
		50 000	198*	185*	172*	159*	146	133	123	111	101	91	82	74	66	58	51	44	39	(33)*	(28)			
		100 000	181*	168*	154*	142*	129*	118	106	96	86	77	69	61	53	46	40*	35*	(30)*	(25)*	(22)*			
		150 000	171*	158*	145*	132*	121*	109*	98*	88*	79*	76*	63*	55*	48*	42*	36*	(32)*	(28)*	(24)*	—			
		200 000	160*	151*	138*	127*	114*	103*	93*	83*	75*	66*	58*	51*	44*	38*	(33)*	(29)*	(25)*	(22)*	—			
		250 000	159*	146*	133*	122*	110*	99*	88*	79*	71*	63*	55*	48*	41	36*	(31)*	(27)*	(25)*	—	—			

[1] A = annealed, N = normalised, Q = quenched, S = solution treated, P = precipitation treated, T = tempered.

[2] Mean values of a large scatter band.

[3] Values given in parentheses and marked with an asterisk were obtained by either 'extended time' or 'extended stress' extrapolation and are subject to greater uncertainty.

[4] In case of austenitic steels, no differentiation has been made between boron containing and boron-free casts.

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